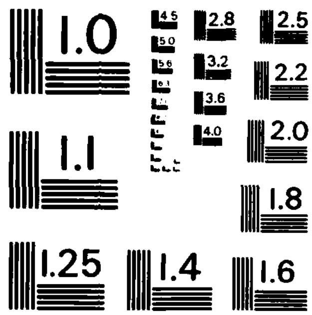
AD-A133 438 THE HUMAN SIDE OF ROBOTICS: RESULTS FROM A PROTOTYPE STUDY ON HOW WORKERS..(U) CARNEGIE-MELLON UNIV PITTSBURGH PA ROBOTICS INST L ARGOTE ET AL. MAY 83 1/1

UNCLASSIFIED CMU-RI-TR-83-11 F/G 6/4 NL

END
DATE
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The Human Side of Robotics: Results from a Prototype Study on How Workers React to a Robot

Linda Argote, Paul S. Goodman and David Schkade

CMU-RI-TR-83-11

THE ROBOTICS INSTITUTE

Carnegie-Mellon University

The Robotics Institute

Technical Report

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD-A133438

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CMU-RI-TR-83-11	2. GOVT ACCESSION NO. AD-A133 438	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE HUMAN SIDE OF ROBOTICS: RESULTS FROM A PROTOTYPE STUDY ON HOW WORKERS REACT TO A ROBOT		5. TYPE OF REPORT & PERIOD COVERED Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Linda Argote, Paul S. Goodman and David Schkade		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Carnegie-Mellon University The Robotics Institute Pittsburgh, PA. 15213		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Arlington, VA 22217		12. REPORT DATE May 1983
		13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Approved for public release; distribution unlimited		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The Human Side of Robotics: Results from a Prototype Study on How Workers React to a Robot

Linda Argote, Paul S. Goodman and David Schkade

CMU-RI-TR-83-11

Graduate School of Industrial Administration and
The Robotics Institute
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

May 1983

A

Partial support for this study was provided by the Graduate School of Industrial Administration and the Robotics Institute of Carnegie-Mellon University. The conclusions reached in the paper are the authors' and do not necessarily reflect the views of the funding institutions. The authors wish to thank members of the organization we studied for their cooperation and assistance. We also wish to thank Robert S. Atkin, Daniel Berg, Dennis Epple, Mark Fichman, Lars P. Hansen, Thomas Morton, Katherine Schipper, Lee S. Sproull, Robert I. Sutton, and Paul K. Wright for helpful comments. An earlier draft of this paper was presented at the meetings of the American Psychological Association, Washington, DC, August 1982. A shortened draft of this paper appeared in the *Sloan Management Review*, 1983, *24*, 31-41.

83

ABSTRACT

This study examines workers' reactions to the introduction of robots in a factory. The study focuses on understanding workers' psychological reactions to this new technology and to the manner in which it was introduced. Workers reported that both advantages (lower fatigue) and disadvantages (increased downtime) were associated with the introduction of the robot. Over time, workers' beliefs about robots became more complex and pessimistic. Production operators' jobs, as well as their interaction patterns with other production and support workers changed with the introduction of the robot. Consequences of these changes for increases in job stress are examined. A set of strategies for introducing robots in the factory is discussed.

Table of Contents

1 Introduction 1
2 Research Site and Methodology 3
3 Results 4
3.1 Beliefs about the Robot 4
3.2 Beliefs about the Effects of Robots 5
3.3 Beliefs about Introducing Change 7
3.4 Activities of Production and Support Workers 7
3.5 Interaction Pattern 10
3.6 Changes in the Organizational Unit 11
4 Discussion 11
4.1 Strategies for Introducing Change 12
I. COMPARISON BETWEEN EMPLOYEES INTERVIEWED AT TIME ONE AND TIME TWO ON KEY CHARACTERISTICS 20

List of Tables

Table 1:	WORKERS' DESCRIPTIONS OF ROBOTS	15
Table 2:	WORKERS' BELIEFS ABOUT ROBOTS IN GENERAL TIME TWO	16
Table 3:	PERCEPTIONS OF THE EFFECT OF A ROBOT IN A PRODUCTION DEPARTMENT	17
Table 4:	PERCEPTIONS OF THE EFFECT OF A ROBOT ON WORKERS' JOBS	18
Table 5:	EFFECTIVENESS OF COMMUNICATION ABOUT THE ROBOT: TIME ONE	19

1 Introduction

Robots are being used in increasing numbers in offices and factories throughout the world. However, little is known about how robots affect either individual workers or the structure, functioning and effectiveness of organizations. This paper focuses on workers' reactions to the introduction of a robot in a factory. We examine how workers react to the robot itself, as well as how various strategies for introducing robots affect these reactions. This knowledge should enable managers to make better decisions about the use of robots in their organizations.

In general, robots can be thought of as machines that can sense, think and act, in repeatable cycles. However, given the current state of robotic technology the sensing and learning functions are not well developed. Thus, we will view robots as (electromechanical) devices with multiple task capability and programmability. The current functions of most robots in U.S. factories are to transfer material and to do certain processes such as welding.

Currently, industrial robots are in limited use -- estimates range from 3,500[1] to 5,000[2] in the U.S. in 1980. There are, however, many reasons to believe that the number of robots used in this country will increase.[3] These reasons include high labor costs, the current emphasis on productivity, and technological improvements in capabilities and costs of robots.

Increased interest in the social impact of robotics has accompanied the use of robots. Questions have been asked about: how the use of robots will affect employment levels,[4] which jobs can be performed by robots,[5] and what types of educational and training programs are needed for workers whose jobs are affected by robots.[6]

This study differs from other work on the social impact of robotics by examining how individual workers react to the introduction of a robot at their factory. Our focus is on understanding workers' psychological reactions (e.g., their attitudes and motivations) to the robot and to the manner in which the robot was introduced. The more positive workers' reactions to robots are, the more likely organizations will experience positive economic consequences such as increased productivity through the use of robots.

While this study appears to be one of the first that examines the effects of introducing a robot in a factory on individual workers, there is literature on the impact of technological change on individuals and organizations. Several themes emerge from that literature which should help our understanding of the effects of robots in the work place. One theme is the need to take into account the compatibility between an organization's technology, its structure, and its members.[7] Failure to consider these factors often results in unintended negative consequences, including increased absenteeism, higher accident rates, and decreased productivity.

Another theme from studies of technological change is that changes in technology often lead to changes in the job activities of individual workers. Whyte[8] found that automation increased the extent to which jobs were mentally demanding. Elizur[9] and Mann and Hoffman[10] found that workers in automated organizations reported a greater sense of control and responsibility than their counterparts in less automated organizations. Workers in automated organizations often report a greater sense of pressure than workers in less automated organizations.[11]

Technological change also affects social interaction patterns at work. Whyte[12] found that increased automation decreased the opportunities workers had to interact with their coworkers. Williams and Williams[13] noted that new technologies often create new demands on support personnel and require more coordination activities between support and production personnel.

Another theme from the organizational change literature is that worker involvement in the design of change affects worker acceptance of, and commitment to, the change.[14] In their classic study, Coch and French[15] found that worker participation in the design of change was associated with higher productivity, lower turnover and fewer acts of aggression against the company. Similarly, Griener[16] and Crockett[17] both stress that change attempts are more likely to be successful if everyone affected by the change is involved in its design and implementation.

While this review is not meant to be exhaustive, it indicates that workers can resist technological change and that the opportunity to participate in the change may reduce levels of resistance. The review also indicates that technological change can affect social interaction patterns on the job. Decreases in the opportunity to interact with others are generally associated with increases in worker alienation, stress, and absenteeism. The review also suggests that new technologies can change work activities. If the change decreases feelings of variety, autonomy and challenge, or introduces activities that are incompatible with the workers' abilities and preferences, it is likely that workers' attitudes will become more negative and their motivational levels will fall.

While robots may be viewed as another advance in automation, we believe that workers may view robots as qualitatively different from other forms of automation. Workers have been exposed to robots with glorified capabilities on television and in the movies. In addition, a robot often directly takes the place of a worker. We think these factors combine to make the introduction of a robot a very salient and possibly threatening event for workers.

2 Research Site and Methodology

To understand how workers react to the introduction of a robot, data were collected at a manufacturing plant that was installing its first robot. The plant had been in operation for approximately ten years. The primary technological processes in the plant involved the forging and machining of various metal alloys. The work force at the plant numbered about 1,000, was nonunion and predominantly blue collar. The work force was fairly stable. For example, the average length of service of employees in the department where the robot was introduced was eight years. Relationships between labor and management appeared to be good. No walkouts or other examples of industrial strife had occurred at the plant in recent years.

The company had used a fairly comprehensive set of strategies to introduce the robot into the plant. These strategies included an open house in which the operation of the robot was demonstrated, talks by the plant manager, discussions with first line supervisors, and notices posted in the cafeteria. The company had informed employees that a robot was going to be introduced at the plant about a year before the robot was actually put into operation.

The robot was introduced in a department in which the basic operations were the milling and grinding of bar stock. There were approximately ten different operations in the department. A total of 40 persons worked across the department's three shifts. Machines were physically arranged in a horseshoe-like configuration. Each person operated one or more of the milling and grinding machines.

The workflow in the department was primarily sequential. Workers moved products from one operation to another by hand. There was some flexibility in the order in which products went through the various operations. The majority of the products went through most of the operations; however, not every product went through every operation. There were some buffer inventories between operations.

The robot was placed at the beginning of the workflow in the department. The robot loaded and unloaded two milling machines. One person operated the robot on each shift.

We interviewed production workers on each shift in the department where the robot was introduced before and after the robot was put on line. These production workers were our primary sample. Interviews were conducted with them during two separate visits to the plant in 1981, about 2 1/2 months before and 2 1/2 months after the introduction of the robot. The individuals we interviewed during the second visit were the same as those interviewed during the first; however, some workers that participated were not available at the time of the second due to factors such as vacations and illness. During the first visit, 37 employees from the department in which the robot was introduced were interviewed; during the second visit, 25 were interviewed.

In addition to interviews with members of our primary sample, approximately 30 supplemental interviews were conducted. These included interviews with first and second line supervisors and managers, interviews with production workers in an adjacent department, and interviews with individuals from engineering, maintenance, personnel relations, and other plant staff. Each interview lasted about 30 minutes and contained both structured response and open-ended questions concerning the robot and the circumstances surrounding its introduction. We also observed the workforce during the introduction of the robot and administered a satisfaction questionnaire to production workers.

We examined whether our primary sample of employees (i.e., employees in the department where the robot was introduced) at Time 2 differed from those we interviewed at Time 1 on characteristics such as the length of time employees had worked at the plant, their job grade, and shift. Our Time 2 sample was drawn without replacement from the population of employees we interviewed at Time 1; hence our Time 2 sample was not independent of our Time 1 population. Therefore, we used the hypergeometric distribution to test whether our Time 2 sample was representative of our Time 1 population. We derived from our Time 2 sample maximum likelihood estimates of the frequencies of individuals in various categories (e.g., first, second, or third shift) in the population most likely to have generated our sample. We then computed a χ^2 test statistic which compared the probability of drawing out Time 2 sample from our Time 1 population to the probability of drawing our Time 2 sample from the population most likely to have generated it.[18] The results of these analyses are presented in Appendix 1. The χ^2 values were not large enough to reject at more than moderate levels of significance ($p < .25$) the hypothesis that our Time 2 sample was a random sample drawn without replacement from the population of employees we interviewed at Time 1. Thus, our sample at Time 2 appears to be representative of our population at Time 1 on these variables.

3 Results

The results are organized in terms of the effects the robot had on worker beliefs, activities, and interactions. Then we examine the effects of introducing the robot on properties of the organization.

3.1 Beliefs about the Robot

We are curious about how workers in our sample think about robots, so we asked the respondents an open-ended question: How would they describe a robot to a friend? Table 1 lists the phrases used to describe a robot. The major concepts seem to be: mechanical man, preprogrammed machine, something that loads machines, increases productivity or reduces manual work. This list of descriptions seems to fall into three categories: general descriptions (mechanical man), functions (loads machines), and consequences (reduces manual work). An examination of the frequency of concepts used in the different classes during Time 1 and Time 2 shows no significant changes.[19] That is, the genera types of categories used to describe robots remain

the same. However, we found a significant increase in the number of concepts mentioned by each individual over time, $t(24) = 1.89$, $p < .10$. This is consistent with the idea that more experience should lead to a more differentiated view of robots.

As a follow up to the first question, we asked workers how they learned about robots. The movie *Star Wars* and television shows depicting humanlike robots were frequently mentioned. These humanlike robots in the media probably contributed to the tendency we observed at the plant for workers to anthropomorphize the robot. Workers on each shift named the robot and endowed it with human qualities. This tendency was evident in both the interviews and in observations of people in the workplace.

3.2 Beliefs about the Effects of Robots

Table 2 presents workers' beliefs about robots in general at Time 2. Seven questions or statements were read to the respondent, who then responded by strongly agreeing, agreeing, slightly agreeing, slightly disagreeing, disagreeing, or strongly disagreeing. The results indicate that workers in our sample had positive attitudes toward robots. The workers felt that robots will help the United States remain competitive. There is some indication that workers believed that robots will displace other workers but not themselves, and be limited to certain types of jobs. Workers perceived that the use of robots will mean that workers require additional education and skill training.

Table 3 focuses on workers' perceptions of the effects of the robot in their department rather than their general beliefs about robots. The respondents were presented with an outcome (e.g., the chances of an accident) and asked at Time 1 whether the robot would increase, decrease, or have no effect on that outcome. Respondents were asked at Time 2 whether the robot had actually increased, decreased, or had no effect on the outcomes. Table 3 presents the information for Time 1 and Time 2 separately in percentages. For example, consider the chances for an accident outcome in Table 3. The results presented in Table 3 indicate that 11 percent of our respondents at Time 1 thought the robot would increase the chances of an accident; this number had increased to 29 percent at Time 2. The number of respondents who thought the robot would decrease the chances of an accident was 41 percent at Time 1; 21 percent of our Time 2 respondents thought the robot had decreased the chances of an accident.

The results of the probit analyses[20] which tested whether there were significant changes in the number of responses in the increase, decrease, or no effect categories from Time 1 to Time 2 are also presented in Table 3. For example, the results of the probit analysis on the chances of an accident outcome reveal that the coefficient of time in the probit model for accidents was -0.687. This indicates that respondents were more likely at Time 2 than at Time 1 to move in the direction of saying the chances of an accident increased. This coefficient was large relative to its standard error, $t(52) = -2.19$, $p < .05$.

Table 3 indicates that a majority of the workers at Time 2 felt that robots increased productivity, but did not have much effect on the quality of output, the amount of downtime, or the number of people who work in the department. The results of the probit analyses indicate that workers were significantly more likely at Time 2 than at Time 1 to say that the robot increased the chances of an accident, increased costs, and lowered the quality of the output. This change in perceptions over time was highly significant for the quality of the output, $t(52) = 3.39$, $p < .001$.

Table 4 uses the same format but focuses on a different set of outcomes. The general trends at Time 2 seem to be that the robot decreased the number of boring jobs and reduced fatigue on the job. A majority of workers believed that robots require workers to learn greater skills, which is consistent with the information in Table 2.

The results in Tables 3 and 4 suggest that workers in the department where the robot was introduced became less optimistic over time about the effects of the robot. Examining the coefficients of the time variable for the eight outcomes on which we have data for both Time 1 and Time 2 reveals that respondents were less optimistic about the effects of the robot on six of these eight outcomes at Time 2 than they were at Time 1. The coefficients for three of these outcomes (accidents, costs, and quality) were significant. The only exceptions to this trend toward greater pessimism are the nonsignificant coefficients for the number of people who work in the department and the number of jobs that are highly skilled.

These questions were also asked of production workers in a department adjacent to the one in which the robot was introduced in order to understand how perceptions of workers in other departments in the plant were affected by the introduction of the robot. Workers in this adjacent department had access to some of the same sources of information about the robot (e.g., the demonstration, the plant manager's talk, and the notices discussed above) as did workers in the department with the robot. Workers in the adjacent department were also able to watch the robot operate. The pattern of results obtained from workers in the adjacent department was similar to that described previously for our primary sample.[21] There was some evidence that workers in the adjacent department were more optimistic about the effects of the robot at Time 2 than were their counterparts in the department with the robot. For example, workers in both departments were more likely at Time 2 than at Time 1 to say that the chances for an accident increased and that costs increased; however, workers in the adjacent unit thought that the chances for an accident and costs increased to a smaller extent than did workers in the department with the robot.

3.3 Beliefs about Introducing Change

In order to understand how workers actually learned about the robot, we asked the employees at Time 1 a series of questions about whether they learned about the robot from a particular source and about the extent to which the source increased their understanding of the robot. These data, presented in Table 5, indicated that the most frequently mentioned source of information about robots was the weekly workplace meeting between supervisors and workers. However, these meetings increased workers' understanding of robots only to a little extent. Written communication and the demonstration at the open house were the most effective sources of information about the robot. However, less than half of our respondents attended the open house and only 16 percent reported that they received a written communication. Thus, the various communication sources do not seem to have been very helpful in increasing workers' understanding of the robot.

In addition, we asked workers how much influence or involvement they *actually had* on decisions about: (1) whether the robot would be introduced in their department, (2) where it would be placed, and (3) who would run it. Also, we asked them how much influence they *should* have had. The workers reported they had no influence on any of these three decisions. They said they should have had a little influence on decisions about whether the robot would be introduced and who should run it. Workers did not think they should be involved in decisions about where the robot was placed.

3.4 Activities of Production and Support Workers

Our analysis thus far has focused on beliefs. Now we turn to the question of how the robot introduction affected workers' activities. Our sample now is composed of the individual on each shift who operated the robot. Special interview schedules were developed to measure the activities, work cycle, and interaction patterns of the operators' jobs before and after the robot was introduced.

When the robot was introduced, a manufacturing cell (i.e., a set of interdependent machines operated by a worker) was created. The robot provided material handling functions for two milling machines. An operator was then responsible for the two milling machines and the robot. The introduction of the robot removed the materials handling activity from the operator's job and added a new activity, robot operator.

Prior to the robot's introduction, approximately twelve different products were passed through both milling machines to begin the work flow sequence for this production department. The work cycle for each machine included set up activities and then relatively short milling times (1-2 minutes) during a product run. Work was done to fine tolerances and it was possible for the operator to determine, through some measurement procedures, whether the parts were milled correctly. The major quality control activity, however, was at the end of all the machine operations.

After the change, the number of products remained the same. The two milling machines were still located at the beginning of the work cycle where the bar stock went through the first two milling operations. The other machine operations were unchanged. Quality control activities were still at the end of all the machine operations.

The major change in activities in the new manufacturing cell came in the material handling activities. In the old system, the operator would pick up the stock, place it on machine one, clamp it in, start the machine, and then the milling machine would perform its work. Then the operator would stop the machine, unclamp the stock, place it on the second machine and the cycle would repeat. Each new stock would follow this cycle. When we asked the operators about the differences between their jobs before and after the robot introduction, they said:

> Now it's mainly watching . . . walking around the machines to be sure everything is running.
>
> We do more activities. Now you have to set up all three machines.
>
> There are also more functions . . . you need to program the robot.

So we see a shift from manual to cognitive activities (monitoring). Also, the operators reported that they were doing more activities and that the total work cycle had increased. The increased work cycle was attributed by the operators to more set ups and delays in getting the new robot operational.

The change in activities was related to a change in skill requirements. The operators said:

> The job now requires more skills. . . . You have to learn how to program the robot and run it. . . . With more skills of course comes more responsibility.
>
> Operating the robot requires more skills . . . the job is more sophisticated.

If we combine the ideas in these quotations with those in the preceding ones, it is clear that the new skills appear in the area of observing and detecting problems in the interface between the three machines, and in programming and operating the robot.

What are some of the consequences for the worker that result from these changes in activities? The general literature on the relationship between job activities and individual characteristics indicates that improving the fit between the new job activities and the personal characteristics of the worker can lead to more positive attitudes and higher motivation. Conversely, introducing activities that are incompatible with a worker's abilities and preferences is likely to generate stress, negative attitudes, and lower motivation. Given that we are examining the introduction of a single robot and are dealing with only three operators, it is difficult to identify statistically significant changes in our study. However, some trends are evident. The operators in our study experienced more stress or pressure. Interview comments from two of the operators were:

> There is more stress now. . . . We have more responsibility. . . . They want the robot to run and we have to keep it going. . . . That's hard because it is still relatively new.

> It's nerve racking . . . there are lots of details . . . it's an expensive piece of equipment.

This stress stems partly from the new tasks and responsibilities of the operators, and partly from operating a new and costly piece of equipment. There was another more subtle source of stress which arose from workers' comparing themselves to the robot. There was much speculation during our first visit to the plant about whether an operator who was particularly quick would be able to beat the robot. By our second visit, workers seemed resigned to the fact that the robot would always be able to outproduce a human worker. The reason was simple: Robots do not take breaks or even go to lunch!! Objectively, after the robot introduction, the operators controlled the robot and the two milling machines. However, operators subjectively viewed the situation as one of competition between them and the machine. Operators reported that the robot could load and unload the two milling machines faster than the operators could when they operated the machines manually. This may be another source of stress.

One of the robot operators in our sample mentioned that although he found observing and monitoring more boring than manual activities, he was currently satisfied with his job because there were still many manual set-up activities. The operator commented, however, that without these set up activities, the current job would be more boring than the previous job. We think this incompatibility between activities required by the job and preferences of the worker was another source of stress.

Now, the picture we want to draw is not one of an unhappy operator. All these individuals voluntarily accepted the job of operating the manufacturing cell. They all received considerable recognition because of the "newness" of the robot. All operators acknowledged that the prior heavy and fatiguing work was eliminated by the robot. The robot operators reported approximately the same degree of satisfaction with most aspects of their job before and after the robot was introduced.

At the same time, workers experienced more stress than they had experienced in their prior job. We have attempted to identify potential sources of this stress. It would be premature at this point to speculate whether this increased stress was good or bad for the individual or the organization. Studies have shown that increased stress is associated with increased turnover and absenteeism[22] and that stress can lead to either increments or decrements in performance.[23]

Since the introduction of the robot could affect support personnel activities as well as operators, we interviewed people in engineering, maintenance, quality control, and scheduling. Engineering and maintenance were responsible for getting the machine up and running. Changes in the functioning of the

machine could affect quality control and scheduling. Several themes emerged from our discussions with support personnel. First, some support personnel felt the robot had changed their job activities. Since the robot represented a new generation of technology, new knowledge and new job activities were necessary. Second, there were some feelings of frustration since not all of the support personnel were involved in planning the introduction of the robot, yet they were expected to acquire new knowledge and skills. Third, there were positive feelings associated with being recognized and personal pride derived from the successful operation of the robot. And fourth, the magnitude of changes in activities and feelings was relatively modest, given that we are dealing with only one robot installation.

3.5 Interaction Pattern

Of importance in the work place are the formal and informal interactions that develop around job activities. The introduction of a robot can change these interaction patterns, which in turn can have psychological and behavioral consequences. For example, if the new technology breaks up existing social interactions and isolates the worker, we expect increases in alienation and more resistance to the new technology.

The robot operators reported at Time 2 that they had less opportunity to talk with people on the job than they had before the robot was introduced. Two of the operators said:

> I haven't been able to talk as much. . . . I'm too involved with the robot. . . .You really have to concentrate.

> I don't have time to talk with anyone. . . . I don't want them breaking my concentration. . . . I'm isolated now.

The decreased opportunity to interact with others seemed to derive mainly from the increased mental demands of the job. Workers had to concentrate more. They did not have time to talk with coworkers.

The introduction of the robot did not change the work flow in the department. All the workers, including the robot operator, were located in the same area and participated in the same part of the work flow. Thus, while our operators reported less opportunity to interact with others in the department, the set of people they interacted with within the department remained roughly the same. This might have provided built-in support mechanisms to buffer the workers from some of the effects of the change.

The major changes in interactions occurred between support personnel from engineering and maintenance departments and the operators of the manufacturing cell. There was more frequent contact among engineering, maintenance, and the robot operator. Perhaps because the robot was new and represented the first major installation in this factory, support personnel as well as the robot operators were highly motivated to get the robot up and running, and cooperated with each other. If there were many robots being placed on line and the support personnel had great demands on their time, then we might find more conflict between support personnel and operators.

3.6 Changes in the Organizational Unit

Our discussion thus far has focused exclusively on the effects of the robot on the individual. The introduction of this new technology also affected the department. Specifically, the introduction of the robot required a re-evaluation and reclassification of the operator's job. Because certain job activities were eliminated and other activities were added, the question was whether the net change indicated that the job should retain the same grade or be upgraded. Management did upgrade the job, but workers felt that the new grade and associated pay for the operator's job were still too low.

We also examined whether the introduction of the robot affected other department policies, procedures, or formal coordination mechanisms. There was no evidence of any effect other than the changes in the pay system.

4 Discussion

The purpose of this paper is to focus our attention on the consequences for the worker of introducing robots into the factory. Workers in our sample held positive beliefs about robots in general. When we asked them about the effect of the robot on their department, they initially reported that the robot would increase productivity, reduce costs, increase quality, make the job easier and less boring, and increase skill requirements. As workers acquired more experience with the robot, their beliefs about robots became more complex and somewhat more pessimistic (greater chances for accidents, cost increases, quality decreases).

We examined how the introduction of the robot changed the production operators' work activities. The operators' work activities shifted from primarily manual activities (lifting) to cognitive activities (monitoring). The operators reported that they were performing more activities and had more responsibility. The changes in activities were related to feelings of more stress. Of course, there were offsetting benefits as the most tiring aspects of their jobs had been eliminated and the robot operators received greater recognition and remuneration as the first robot was put on line. Changes in activities also appeared in the jobs of support personnel. Again, there was some evidence of stress created by the new work activities.

Interaction patterns changed for the robot operators. Operators reported that they felt isolated and did not have as much time to interact with coworkers in their department. There was more frequent contact between individuals from engineering and maintenance and the robot operators. However, the modal job and social interaction patterns for the department before and after the robot introduction remained essentially the same.

The introduction of the robot had an impact at the organizational unit level, particularly in the area of job evaluation and pay. There was a widely-held belief on the part of the workers that the robot operator job had been unfairly evaluated and the pay grade was too low.

The process of introducing technological change was also examined. The basic finding was that there was a discrepancy between management's attempt to communicate about robots and the workers' need to learn about robots. That is, although many communication techniques were used, few were received by the workers. Those communications received by workers were not seen as particularly helpful in increasing their understanding of the robot.

We think this study has several major strengths. To our knowledge, it is the first systematic evaluation of the effect of introducing a robot on workers. The study used a variety of methods, including interviews, questionnaires, and observations. We collected data before and after the change to get some baseline to study the effects of the introduction over time. In addition, we used a broad sample perspective to identify people directly affected by the change as well as those indirectly affected (e.g., support personnel).

The study, of course, has certain limitations. Data were collected from only one organization. There was only one robot installation and it was the first robot installation. The change also took place in a non-union organization where there were positive relations between labor and management. While interview data on the effects of the robot on various outcomes such as productivity were collected, company records data on these outcomes were not collected. Future research involving multiple organizations and including records or archival data as well as interview data collected over several points in time (e.g., before, shortly after, and a year or so after the robot introduction) is needed.

What can we learn from this study that will help in new installations of robotics in factories? Despite the small sample size and the difficulty of systematically testing certain relationships, a number of findings have emerged from this study. These findings *combined with* findings from other studies of increased automation suggest some possible recommendations for managers introducing new technologies.

4.1 Strategies for Introducing Change

1) Prior to any introduction some questions need to be resolved. Questions concerning job security and pay are likely to be uppermost in the minds of the work force. Failure to resolve these questions prior to the introduction of the robot is likely to reduce the effectiveness of the introduction.

2) Diagnosis of the organization prior to introducing change is critical. What effects will the technological change have on activities, interactions, and beliefs of workers? Problems caused by the change need to be anticipated--some will be obvious (in cases of job loss) while others will be subtle (in cases of new job activities).

3) A strategy for worker involvement in introducing this new technology needs to be delineated. There are

a wide variety of possible strategies. Management in our study provided virtually no opportunities for worker involvement in this technological change. The workers wanted some levels of involvement for certain decisions but not others. Some levels of involvement are likely to increase understanding about the robot and perhaps lead to greater commitment to the change process.

4) Certain communication techniques seem more effective than others in introducing robots. Demonstrations that illustrate the operations of a robot seem to be powerful techniques.

5) Some feedback mechanism to monitor communication effectiveness is necessary in introducing this technology. Our study showed a discrepancy between what management was trying to communicate to workers and what the workers received.

6) It is vital that first line supervisors be given information about the robot and support from upper management in dealing with workers' reactions to the robot. In times of change, workers are likely to go to their supervisors more frequently for information and advice. The attitudes and behaviors of supervisors are likely to have a big effect on the success of the robot introduction.

7) The robot will create new job activities. It is very important to do a careful analysis of the new job and maximize the fit between job characteristics and personal characteristics. The literature on job-person fit indicates that a lack of congruency may have dysfunctional effects on the person and organization. The question is not whether the worker can do the new activities but whether the worker *can do* and *prefers* these activities. If there is lack of congruency, one must consider alternatives in job redesign or in selection procedures.

8) If the change is from "doing" to "observing" activities, the workers may experience more boredom in the job. If this occurs, some mechanism to alleviate boredom, such as job rotation, may be helpful. The job rotation would increase task variety and build up a backlog of skills for future expansion of robotics.

9) Training backup operators for the robot is important. In our study only one person per shift was initially trained to operate the robot. This led to disruptions in the work process when one of the operators was absent. Training backup operators would provide the organization with more flexibility and individual workers with more job variety.

10) The introduction of robots can affect the nature of social interaction patterns at work. Prior research shows that attempts to change these patterns can generate resistance to change. If diagnosis indicates that the change will break up existing social relationships, some alternative strategies need to be conceived. For

example, involving the worker in this part of the change may generate new work arrangements that will facilitate the acceptance of change.

11) A successful introduction of robots requires the cooperation of the support personnel. Our study showed that not all of the support personnel were involved in planning the introduction of the robot, and some stress was created as a result of the lack of participation. Involvement of the support personnel and operators early in the change process should facilitate the introduction process.

Table 1: WORKERS' DESCRIPTIONS OF ROBOTS

	Percent of Total Mentions	
	Time 1	Time 2
Mechanical Man	15%	9%
Hydraulic Arm	2%	9%
Computer	6%	0%
Preprogrammed Machine	15%	16%
T.V. Image	10%	7%
Moves Material	4%	9%
Loads Machine	12%	14%
Better Productivity	15%	5%
Reduces Manual Work	15%	23%
Works Continuously	6%	8%
	100%	100%

Table 2: WORKERS' BELIEFS ABOUT ROBOTS IN GENERAL
TIME TWO

	Percent Workers Agreeing/ Strongly Agreeing
Robots will:	
Make the U.S. more competitive	87%
Be capable of doing my job	29%
Be capable of doing clerical jobs	8%
Be capable of doing management jobs	17%
Displace workers	50%
Create less desirable jobs	21%
Require more job retraining	87%

Table 3

PERCEPTIONS OF THE EFFECT OF A ROBOT IN A PRODUCTION DEPARTMENT

Percent[a] of Respondents Who Replied that the Robot Had a Certain Effect on:

	Productivity		Likelihood of Accidents		Costs		Quality		Number of People	
Effect:	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Increase	81	67	11	29	10	33	51	17	6	0
No Effect	8	12	32	46	7	4	30	54	44	83
Decrease	3	12	41	21	55	42	3	21	44	17
Coefficient of Time Variable in Probit Model[c]	0.61		-0.69		-0.76		1.17		-0.53	
T-Statistic	1.55		-2.19		-1.88		3.39		-1.64	
Significance	0.13		0.03		0.07		0.001		0.11	

[a]The percent of respondents who replied, "Don't Know," is not included in this table; hence, percentages for some outcomes will sum to less than 100.

[b]A positive coefficient indicates that respondents were more likely at Time 2 than at Time 1 to move in the direction of saying the particular outcome decreased; a negative coefficient indicates that respondents were more likely at Time 2 than at Time 1 to move in the direction of saying the outcome increased.

Table 4

PERCEPTIONS OF THE EFFECT OF A ROBOT ON WORKERS' JOBS

Percent[a] of Respondents Who Replied that the Robot Had a Certain Effect on:

	Boring Jobs		Skill Requirements		Chances for a Better Job		Fatigue	
Effect:	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2	Time 1[b]	Time 2
Increase	16	20	54	64	21	17	--	4
No Effect	19	16	34	36	59	75	--	8
Decrease	59	60	0	0	9	8	--	79
Coefficient of Time Variable in Probit Model[c]	-0.05		-0.07		0.11		--	
T-Statistic	-0.16		-0.21		0.33		--	
Significance	0.87		0.84		0.74		--	

[a]The percent of respondents who replied, "Don't Know," is not included in this table; hence, percentages for some outcomes will sum to less than 100.

[b]Respondents were not asked about this outcome at Time 1.

[c]A positive coefficient indicates that respondents were more likely at Time 2 than at Time 1 to move in the direction of saying the particular outcome decreased; a negative coefficient indicates that respondents were more likely at Time 2 than at Time 1 to move in the direction of saying the outcome increased.

Table 5: EFFECTIVENESS OF COMMUNICATION ABOUT THE ROBOT: TIME ONE

Communication Source	% Workers Reporting that They Received Communication	Average Extent Communication Increased Workers' Understanding[1]
Written communication	16%	2.6
Workplace meetings	89%	4
Communication from supervisor	46%	4.1
Movies or audio-visual presentations	13%	3
Demonstrations	42%	2.7
Informal sources including the grapevine	37%	4

[1]The response alternatives were: (1) to a very great extent, (2) to a great extent, (3) to a fair extent, (4) to a little extent, (5) not at all.

Appendix 1

COMPARISON BETWEEN EMPLOYEES INTERVIEWED AT TIME ONE AND TIME TWO ON KEY CHARACTERISTICS

	Number of Employees Time One	Number of Employees Time Two	Maximum Likelihood Estimates	x^2	df	p
Shift 1	18	10	15	2.28	2	$p < .50$
2	12	10	15			
3	7	5	7			
Grade 7	3	1	1	3.83	3	$p < .50$
8	9	8	11			
9	19	14	20			
10	3	2	2			
Tenure at Plant (PT)						
PT $\leq$ 7 years	10	9	14	3.03	2	$p < .25$
7 years < PT $\leq$ 8 years	16	9	13			
PT $\geq$ 8 years	11	7	10			
Tenure on Job (JT)						
JT $\leq$ 1 year	8	6	9	0.81	3	$p < .90$
1 year < JT $\leq$ 3 years	9	5	7			
3 years < JT $\leq$ 5 years	8	6	9			
JT $\geq$ 5 years	12	8	12			

[1]See "Robots Join the Labor Force." *Business Week*, 9 June 1980.

[2]See A. Salpukas, "Manufacturing Using Robots." *The New York Times*, 23 October 1980.

[3]J. Engelberger, *Robotics in Practice*. (New York: Amacom, 1980).

[4]R. U. Ayres, "The Future of Robotics: A Meta Review," Prepared for the UNESCO/IIASA Symposium on Scientific Forecasting and Human Needs: Methods Trends and Message, Tbilisi, USSR, December 1981.

[5]R. U. Ayres and S. M. Miller, "Preparing for the Growth of Industrial Robots," Unpublished manuscript, Carnegie-Mellon University, 1981.

[6]Eikonix Corporation, "Technology Assessment: The Impact of Robotics," Technical Report EC/2405801 - FR-1, Eikonix Corporation, 1979.

[7]F. E. Emery and E. L. Trist, "Socio-technical Systems," In F. Baker (Ed.), *Organizational Systems: General Systems Approaches to Complex Organizations* (Homewood, IL: Richard D. Irwin, 1973).

[8]W. F. Whyte, *Men at Work* (Homewood, IL: Richard D. Irwin, 1961).

[9]D. Elizur, *Adapting to Innovation* (Jerusalem: Jerusalem Academic Press, 1970).

[10]F. C. Mann and L. R. Hoffman, *Automation and the Worker* (New York: Holt, 1960).

[11]E. Mumford and D. Banks, *The Computer and the Clerk* (London: Routledge and Kegan Paul, 1967).

[12]W. F. Whyte, *Men at Work* (Homewood, IL: Richard D. Irwin, 1961).

[13]L. K. Williams and C. B. Williams, "The Impact of Numerically Controlled Equipment on Factory Organization," *California Management Review*, Winter 1964, pp.25-34.

[14]M. Beer, *Organization Change and Development* (Santa Monica, CA: Goodyear, 1980).

[15]L. Coch and J. R. P. French, "Overcoming Resistance to Change," *Human Relations*, Vol. 1, August 1948, pp. 512-532.

[16]L. E. Griener, "Patterns of Organization Change," *Harvard Business Review*, Vol. 45, No. 3, May-June 1967, pp. 119-128.

[17]W. Crockett, "Introducing Change to a Government Agency," In P. H. Mirvis and D. N. Berg (Eds.), *Failures in Organization Development and Change* (New York: Wiley, 1977).

[18]Details on the use of this analytic procedure are available on request from the first author.

[19]To test whether the frequency of mentions in various categories changed from Time 1 to Time 2, we used a similar procedure to that outlined earlier for testing whether our sample of employees differed from Time 1 to Time 2 on key characteristics. In particular, we pooled the frequency of mentions in each category at Time 1 and Time 2 to arrive at the frequency of mentions in the population. Using the hypergeometric distribution, we then tested whether the distribution of mentions at Times 1 and 2 were random samples drawn without replacement from our population. There was no evidence for rejecting the hypothesis that our Time 1 distribution was a random sample from the population, $\chi^2(2) = 1.04$, $p < .75$, or for rejecting the hypothesis that our Time 2 distribution was a random sample from the population, $\chi^2(2) = 0.82$, $p < .75$.

[20]The N-Chotomous probit model requires independence of the error terms. This requirement might be violated if, for example, observations for the same individual at different points in time were correlated. In using the probit model, we have assumed that this dependence, if it exists, is weak.

[21]The probit analyses on the outcomes discussed above were run separately for each department with time (Time 1 vs. Time 2) as the predictor of the outcomes. The probit analyses were also performed on the data from both departments combined, with both time and department (department with the robot, adjacent department) as predictors of the outcomes. A similar pattern of results was obtained from the different analyses.

[22]L. W. Porter and R. M. Steers, "Organizational, work, and personal factors in employee turnover and absenteeism.: *Psychological Bulletin*, 1973, *80* 151-176.

[23]W. E. Scott, "Activation theory and task design," *Organizational Behavior and Human Performance*, 1977, 111-128.